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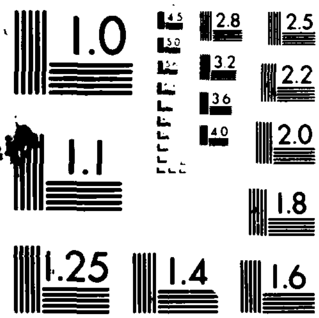

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COMMENCEMENT BAY STUDY

Summary and Synthesis

prepared by

Dames & Moore

for

U.S. Army Corps of Engineers, Seattle District

Volume I

December 1981

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In the 20-month period ending December 1981, Dames & Moore (Seattle) assisted by four subcontractors completed a Phase I effort to collect baseline data and provide a detailed description of the natural and human systems of the Commencement Bay area in the southern Main Basin of Puget Sound in Washington State.

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Data, interpretations, and conclusions in this report are those of the authors.

BASELINE STUDIES AND EVALUATIONS FOR COMMENCEMENT BAY STUDY/ENVIRONMENTAL IMPACT ASSESSMENT

VOLUME I

SUMMARY AND SYNTHESIS

Prepared By

Dames & Moore
Seattle, Washington

for

U.S. Army Corps of Engineers
Seattle District

Contract No. DACW67-80-C-0101

December 1981

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

In March 1980, the U.S. Army Corps of Engineers, Seattle District (hereafter referred to as "the Corps") issued a contract for Baseline Studies and Evaluations for the Commencement Bay Study/Environmental Impact Assessment (COBS). This contract established the scope of services to be undertaken in completing environmental studies within Commencement Bay, in Pierce County, Washington.

The study background, authority, and purpose and objectives from this contract are presented below:

> (Section) 1.1. Background. Commencement Bay has been the object of considerable industrial and commercial development activity over the past decades. The Port of Tacoma is a major port in western Washington and has a continued interest in development and expansion of port and harbor facilities in Commencement Bay and the waterways. Various industries are located in and around the bay, including shipbuilding, shipping, concrete products, storage facilities, and handling of ores, chemicals, metals, petroleum, timber, and other materials. There is significant pressure for continued development of the area, including new marinas and restaurants, expansion of existing industrial facilities, maintenance dredging and disposal of dredged material, fills, and construction of cargo handling facilities.
>
> Various local, state, and Federal agencies with regulatory, planning, and/or resource management responsibilities in the Commencement Bay area have been concerned with future development plans, permit applications, and proposed projects in the bay. Meetings and discussions between the agencies were begun in November 1977 and continued through September of 1978. The result of these meetings was a consensus for a Commencement Bay Study/EIA which would generate new and detailed baseline data and would provide an assessment of plans, policies, projects, and activities in the Commencement Bay area.
>
> The information resulting from the Commencement Bay Study/EIA is intended to be used by Federal and state agencies, the city of Tacoma, Port of Tacoma, Pierce County, the Puyallup Indian Nation, and all other interested groups and persons, to assess possible impacts of proposed development in the Commencement Bay area.

(Section) 1.2 Study Authority. The Seattle District, U.S. Army Corps of Engineers, is engaged in the regulation of activities in or upon the waters of the United States and adjacent wetlands under provisions of Section 10 of the River and Harbor Act of 1899 (30 Stat. 1151; 33 U.S.C. 403) and Section 404 of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500, FWPCA). Within this area, permits for dredging, filling , moorage, and other activities must be obtained from the Seattle District, Corps of Engineers. As lead agency, the Seattle District will conduct the Commencement Bay Study/EIA under the authorities of the Clean Water Act of 1977 and the National Environmental Policy Act.

(Section) 1.3 Study Purpose and Objectives. The overall purpose of the Commencement Bay Study/EIA is to provide baseline data and an environmental assessment of proposed activities, projects, plans, and policies in the Commencement Bay area. The study must present the material in a format that both meets EIA requirements and makes the data useful for assessment of future plans and projects. The objectives of the Study/EIA are:

a. to collect baseline data and provide a detailed description of the natural and human systems of the Commencement Bay area,

b. to present a method for evaluating the environmental impacts of proposed activities in any part of the study area, and

c. to assess and describe the environmental impacts of various projects and plans in the study area.

The scope of work for studies to date is designed to meet the first objective (1.3,a).

All contracted services to date have been directed exclusively at the collection of baseline data and preparation of descriptions of the natural and human systems provided for under Objective 1.3,a (Phase 1).* Information required for the Objective 1.3,a effort was further defined in the contract for the following general areas:

- Fish
- Invertebrates
- Wetlands

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*Efforts directed at meeting Objectives 1.3,b and c are planned subsequent to completion of Phase 1 services.

- Water Quality
- Sediments
- Birds
- Air Quality and Climate
- Noise
- Aesthetics
- Land and Water Use
- Zoning, Land/Water Use Plans and Policies
- Water Related Cultural Resources
- Physical Oceanography

1.2 STUDY AREA

Commencement Bay is a northwest-southeast trending marine body of water located near the southern end of the main basin of Puget Sound in northwest Washington State (see Figure 1). The COBS study area comprises the approximately 9 square miles (2,330 hectares) of Commencement Bay proper as well as an additional 12 square miles (3,105 hectares) of adjacent shorelines and uplands. The study area boundaries, as specifically determined through discussion with the Corps, include: (1) a line from Point Defiance to Browns Point; (2) adjacent lands along the south and north shores of Commencement Bay (which, for the purpose of this study, extend landward either 200 feet on a horizontal plane from the ordinary high watermark or from the ordinary high watermark to the base of the adjacent bluff, whichever distance is greater); and (3) the Port of Tacoma industrial area bounded by Commencement Bay and U.S. Highway 99 to include all waterways and creeks east to U.S. Highway 99 (see Figure 1). Most studies were concentrated inside the 20 m (60 foot) depth contour.

The City of Tacoma dominates the south shore of the bay. The Port of Tacoma and the associated port industrial area occupies the extensively filled and modified Puyallup delta at the eastern end of the bay. The north shore of the bay is dominated by residential areas of northeast Tacoma and unincorporated Pierce County (Browns Point).

A study base map modified from NOAA Chart No. 18453 (Scale 1:15,000) was developed for use by all investigators.

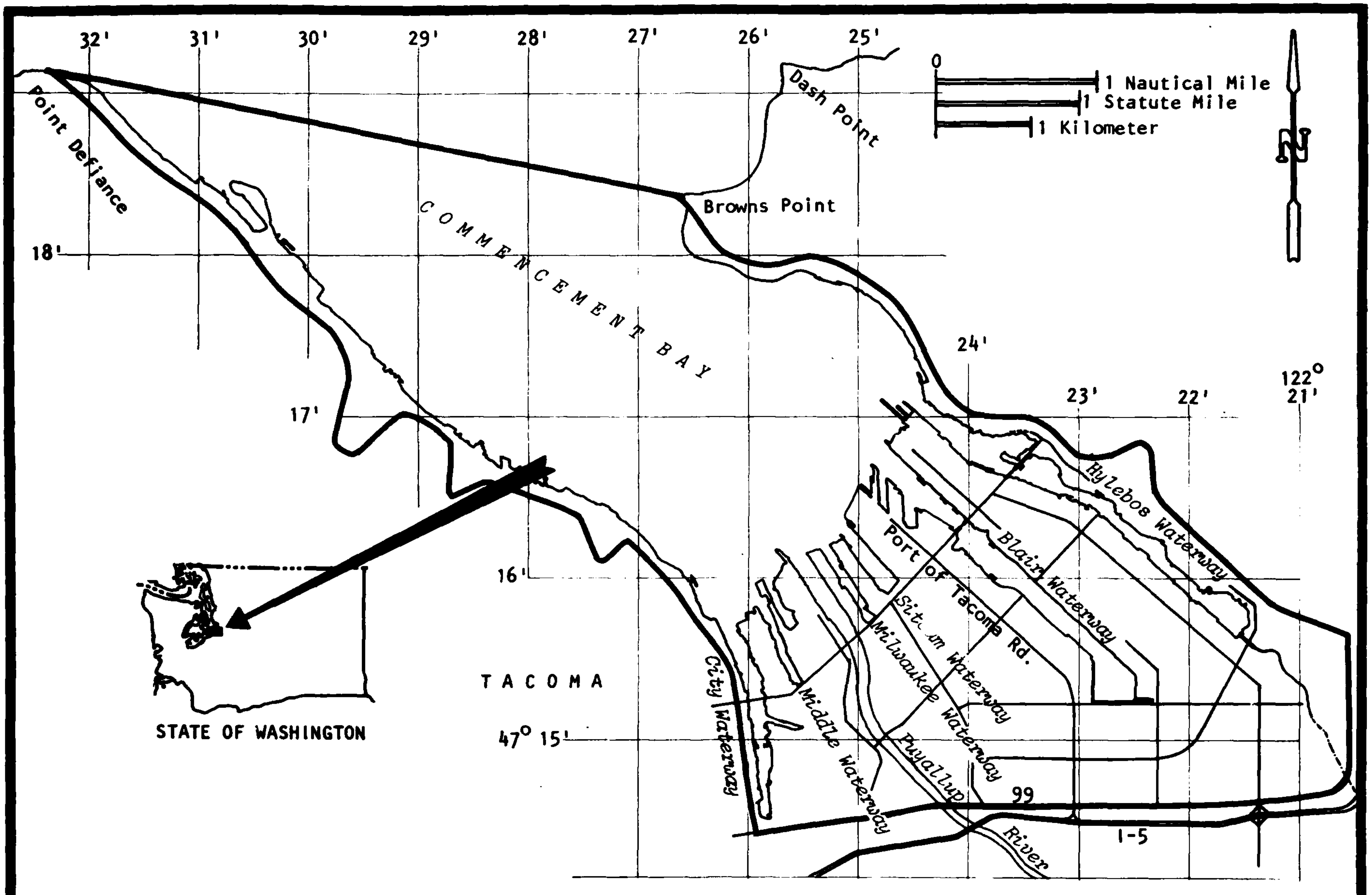

Figure 1
THE STUDY AREA

1.3 STUDY TEAM

The COBS study team included personnel from the contractor, Dames & Moore (Seattle office), and from four subcontractors selected to perform individual tasks. These subcontractors included:

- Parametrix, Inc. - Fish Studies
- Northwest Consultant Oceanographers, Inc. (NCO) - Physical Oceanography
- Shapiro and Associates, Inc. - Wetland Studies
- AM TEST, Inc. - Water and Sediment Chemistry Analyses

Specific individuals who played major roles in each task are acknowledged as authors of the respective Technical Reports in Appendix A of this volume.

1.4 REPORTS

The COBS report series is comprised of seven volumes as follows:

Volume	Study or Studies
I	Summary and Synthesis
II	Land and Water Use
III	Wetlands; Fish
IV	Invertebrates
V	Water Quality
VI	Physical Oceanography
VII	Sediments; Aesthetics, Noise; Air Quality and Climate; Birds

The remainder of this Summary and Synthesis Report (Volume I) provides summaries/overviews of each report (Volumes II through VII) as well as a discussion of key relationships between individual study results based primarily upon the COBS data base (e.g., the relationship of fish use and presence/abundance of invertebrates in specific sampling locations, etc.) Analyses of relationships were facilitated by the preparation of resource maps consisting of a large-scale (1:15,000) base map of the COBS study area and map overlays presenting data generated by COBS and other recent studies. These overlays, not reproduced in this report, are available for inspection at the Seattle District Corps of Engineers.

The synthesis and summary below cannot approach the level of detail incorporated into the technical reports. Therefore, the reader with specific discipline interests is encouraged to refer to the appropriate technical report. Tables of Contents for the 11 Technical Reports in Volumes II through VII are provided in Appendix B of this volume.

2.0 HISTORICAL PERSPECTIVES

Commencement Bay is approximately 2 miles (3.2 kilometers [km]) wide and has a water depth of 560 feet (170 meters [m]) at the entrance. The bay is bordered on the south and north shores by steep wooded slopes. These shorelines are currently dominated by urbanized areas of the City of Tacoma and its suburbs. The east end of the bay is dominated by the port industrial area, a large (10-square-mile [2,590-hectare]) flat area of filled tidelands that supports a variety of industrial and commercial uses, including operations of the Port of Tacoma.

The shoreline of Commencement Bay has been substantially altered since the 1880s as a direct result of urbanization and industrialization of the study area. The wooded bluffs that rose abruptly from rocky beaches abutting the edge of the south shore of Commencement Bay were undercut in the late 19th century to form the narrow shelf that presently supports Schuster Parkway, Ruston Way, and the Burlington Northern Railroad mainline. The north shore of Commencement Bay remains relatively unaltered by man; however, the north shore was extensively logged in the late 19th and early 20th centuries. The east end of the bay, once a broad tideflat formed by the Puyallup River delta and other small deltas, was dredged and filled between approximately 1920 and the late 1960s, resulting in its present configuration. This dredge/fill activity also resulted in the channelization of the lower Puyallup River and the relocation of the Puyallup River mouth. As a result of these activities, approximately 5 square miles (1,300 hectares) of wetlands were eliminated. The Land and Water Use Technical Report (Volume II) presents a detailed description of the historical dredging and filling activities in the study area.

The natural environment, although dramatically altered by man's activities, is used by a variety of resident marine fish, anadromous salmonids, marine invertebrates, and a variety of bird types. Industrial wastes have been discharged into the marine environment since the initial industrialization of the adjacent shorelines. As a result, there is evidence that short- and long-term species diversity and abundance have

been altered by the introduction of these wastes. For example, fish mortalities have been documented in Hylebos Waterway and in other industrial waterways in the 1930s and 1950s. There is some evidence to indicate that water quality and waste discharge practices have improved over the past two decades and that the marine waters of Commencement Bay are becoming less toxic to marine life. However, the introduction of potentially hazardous wastes continues, as do the adverse effects of recent and older contaminants in sediments and fill materials.

3.0 EXISTING PHYSICAL ENVIRONMENT

3.1 GENERAL

The physical environment of the study area has been highly modified by human activities. Activities that have had a direct effect on the physical characteristics of the study area include modification of the Commencement Bay shoreline, industrialization and urbanization of these shoreline areas, and the introduction of runoff and waste discharges from developed shoreline uses. These modifications to the physical environment, resulting in a general degradation of water and sediment quality and a major alteration of the Puyallup River Delta are the greatest influences on the biological environment of shallow (<60 feet [20 m]) areas of Commencement Bay. The existing physical environment was therefore studied with a view toward the interactions of physical systems with existing biological systems.

3.2 PHYSICAL OCEANOGRAPHY

3.2.1 General

Physical oceanographic studies were conducted to evaluate flushing characteristics in the industrial waterways, determine circulation/current patterns in Commencement Bay, and identify and describe wave patterns along exposed shorelines. Drogue studies were conducted to determine circulation/current patterns in both the industrial waterways and the open bay waters. Wave patterns and heights were determined through calculations based on wind, fetch, and other known wave data for Commencement Bay.

The physical oceanography in the industrial waterways is quite complex because the major freshwater input is from the mouth (or bay end) rather than from the head of the waterways as is more typical in other estuarine areas of the Pacific Northwest. Based upon studies in Blair Waterway under both high (February 1981) and low (August 1980) Puyallup River flow conditions, it was determined that tides were the main driving force with winds influencing only the surface waters to 1.5 feet (0.5 m).

The apparent lack of significant Puyallup River influence on City Waterway sets it apart from the other six waterways. The more saline conditions in this waterway contribute to a different density structure in the water column.

The general pattern of flow in waterways, excepting City Waterway, is one of a multi-level system (as many as three or four layers) often moving in opposite directions at close depth intervals resulting in considerable shear. The pattern of flow in a strong flooding tide (not opposed by wind) is a replacement of the upper 3 to 6 feet (1 to 2 m) by incoming bay water with the original surface waters being displaced downward. The base of the pycnocline (greatest change in density as determined by temperature and salinity) appeared to be at about 10 feet (3 m) in both high and low river flow periods.

Waterway currents are generally faster near the waterway mouth than in inner areas except for wind influenced surface flows. Flow reversals with tide change had varying "lag" or "lead" times during high and low tide conditions at depth in each waterway. Flow reversals in shorter waterways were evident in inner and outer segments at the same depth in the same time frame. Longer waterways (Blair and Hylebos) did not exhibit such simultaneous reversals and contrary flows often occurred at the same depth in different waterway segments.

Both wind and tide seem to influence cross-channel flows. Ebb and flood flows in the waterways may meander from side to side, and localized eddies were observed.

Water replacement calculations were made for each waterway. However, lack of information concerning circulation patterns and volume for each waterway required assumptions to be made that created wide ranges in estimated flushing rates. For example, Blair Waterway was calculated to require from approximately 3 (no mixing assumed) to 15 (99 percent mixing) 24-hour days for complete replacement (99 percent). In contrast, a smaller waterway (Middle Waterway) had a range of approximately 0.5 to 4 24-hour days for complete replacement (99 percent).

Studies of currents/circulation in Commencement Bay proper focused more on nearshore rather than mid-bay areas although some drogue tracks entered the latter area. The field studies were evaluated along with other investigators' results to describe general circulation patterns. During summer studies (August-September 1980), a general clockwise flow from the surface to 33 feet (10 m) with a weak counterclockwise trend at 65 feet (20 m) were observed. During the winter studies (February 1981), the clockwise surface flow was still apparent but less pronounced; the deeper counterclockwise trend was not observed.

Currents in the southern pocket of the bay off City Waterway were weak and variable at all depths. This is consistent with other studies indicating that the Puyallup River plume seldom enters City Waterway. COBS data support the hypothesis that the Puyallup River generates a back eddy in this part of the bay.

Residence times in the bay vary with location and depth. Ruston Way shoreline waters have a relatively short residence time with a net transport toward Point Defiance. Waters in the inner bay at and below 16 feet (5 m) exhibit very little net movement and hence have a long residence time. Surface flows of the entire bay are strongly influenced by wind and the Puyallup River. Surface waters appear to exit the bay in less than a day under some conditions. Surface waters of the bay entering waterways can be retained in the waterways for longer time periods under certain tide and wind conditions.

3.2.2 Wave Analysis

A wave analysis was completed for the Ruston and Old Tacoma shoreline. Extreme waves were computed to have significant wave heights of about 5 feet (1.5 m). However, 98 percent of the time the computed wave height was less than 1 foot (0.3 m).

3.2.3 Interactions

The physical oceanography of the COBS study area is the major physical influence in the distribution of toxicants being introduced into the study area waters. The area's oceanography also influences the transport of sediments, nutrients, and detritus within the study area (primarily introduced via the Puyallup River). Both the distribution and rates of deposition of sediments in specific locations is governed largely by prevailing currents and circulation.

Based upon waterway studies, a chemical introduced into the upper meter of water could be quickly dispersed under most conditions, especially in the shorter and smaller waterways. However, vertical mixing of soluble chemicals could be hindered by the layering observed in the water column. The complex water movements, especially in Hylebos and Blair Waterways, will likely make evaluating the source of some chemicals in water samples quite difficult. See further discussion in the following Water Quality section.

Circulation studies in the bay indicate that chemicals in surface waters (above 16 feet [5 m]) will likely be quickly dispersed, especially those nearer the Puyallup River mouth and closer to the surface. Wind and tides can combine to reduce this surface dispersion by moving these waters back into the waterways. Chemicals discharged at greater depths in the bay (below 16 feet [5 m]) could be retained for longer periods of time (relative to the surface discharges). Chemicals entering the waters off the mouth of City Waterway may be slow to disperse, assuming the existence of the aforementioned eddy.

3.3 WATER QUALITY

Existing water quality conditions were determined in two field sampling periods under low and high Puyallup River flow conditions (September and December 1980, respectively). Water quality sampling at 33 stations was directed toward a screening of levels of PCBs and a few selected heavy metals as well as a series of traditional water quality

parameters as required by the COBS contract. Concurrent with this effort, other agencies (e.g., NOAA/MESA, EPA, WDE) have been conducting additional water quality evaluations focusing on heavy metals and organic chemicals. The Water Quality Technical Report (Volume V) provides a list of these completed and ongoing water quality and other related studies directed at identifying other parameters of concern. These reports should be consulted as they become available.

Both the COBS water quality study and past or ongoing investigations by others demonstrate that measurable amounts of chemicals are entering the fresh and marine waters of the COBS area. Higher chemical levels identified are attributable to both point and nonpoint sources as well as to surface sediments that lie at the interface with study area waters.

The December 1980 COBS data for heavy metals and the data of Riley et al. (1981) for organics indicated that contaminant concentrations decline with depth in many locations. Relatively higher levels of contaminants were associated with nearsurface, lower salinity waters, especially in the shallower waterways. This indicates that the potentially toxic chemicals may be entering the system via fresh- or low-salinity water from bank seepages attributable to shallow ground water, surface water runoff, or industrial outfalls (see Malins et al. 1980, EPA 1980a,b). The same pattern of reduced chemical concentration at greater depths also exists within the sediments. Thus, in many waterway locations the water column has low chemical levels near the bottom while the surface sediment layer has relatively higher chemical levels.

In general, COBS data showed that bay stations had significantly better water quality than the waterway stations. This was especially evident in the more offshore and deeper water stations where shorter residence times, lower toxicant inputs, and dilution combined to produce improved water quality conditions.

The single-point collection method used in these water quality studies yields instantaneous values. Conversely, EPA Water Quality Criteria (EPA 1980c), which establish the concentrations of given

toxicants that should not be exceeded to protect marine life, are usually described as 24-hour averages. The criteria themselves cause interpretative problems in Commencement Bay. For example, the criteria are established for single parameter exposure whereas the existing conditions present a multiple toxicant stress to organisms present. A second problem concerns potential differences in sensitivity between species present in the study area and those used to establish EPA criteria for a particular chemical. Testing sensitivities of species tolerant of chemically stressed areas may provide results that underestimate effects of these chemicals on less tolerant species. Testing sensitivities of species not acclimated to chemically stressed areas could provide results which imply that organisms will experience significant effects from a given toxicant level when in fact they have developed a tolerance of that level through chronic exposure.

With no real basis for judging sensitivities of Commencement Bay organisms relative to these 1980 EPA criteria, they were applied only as indicators of potential adverse impacts to local marine biota. Numerous measured levels for heavy metals (arsenic, copper, lead, and zinc) and one PCB level in the COBS study exceeded or approached the single parameter 1980 EPA criteria. By comparison, Riley et al. (1981) measured PCB levels that exceeded the 24-hour 1980 EPA criteria at all stations (except at one depth at one station) in Hylebos and Blair Waterways.

As discussed below (Section 4.0, Existing Biological Environment), marine biota in the area have been influenced by past and present water and sediment quality. Invertebrate populations in many COBS area locations were low in species number but high in number of individuals within a few species. This is often found in areas of high stress and can be related to such factors as chemical contamination or high organic content. Malins et al. (1980) reported statistical correlations between contaminant concentrations in some Puget Sound fish and shellfish and tissue abnormalities in these organisms. Swartz (1981) demonstrated through sediment bioassays that the more contaminated sediments in Commencement Bay are toxic to selected invertebrates.

Additional field and laboratory effort is required to more fully understand the relationships between water/sediment quality and local freshwater and marine biota. Results of an ongoing NOAA/MESA sediment toxicity bioassay program including stations in Commencement Bay and other projects are expected in 1982.

3.4 SEDIMENTS

Sediment studies were completed in the COBS area to identify existing conditions, determine sedimentation rates, determine Puyallup River delta growth trends, and to evaluate maintenance dredging in the area.

Sediment sampling was completed in August 1980, with 15 sediment samples collected by SCUBA divers from 13 general locations. These samples were then subjected to the bulk sediment and elutriate analyses often required for Corps of Engineers permit applications involving dredged material disposal. The physical characteristics of these sediments were found to vary from sandy silts and silty sands at most locations, sandy sediments in the Puyallup River mouth, to gravelly sediments along the more exposed shoreline of the bay.

On the basis of chemical parameters (chemical oxygen demand, volatile solids, sulfide, and oil-grease), the least contaminated sediment conditions in the study area were at stations outside the waterways. Zinc concentrations in elutriate analyses exceeded 1980 EPA water quality 24-hour criteria (0.058 ppm) at both the Old Tacoma station off Ruston Way and near the ASARCO smelter. Elutriate analyses indicated copper levels exceeded the EPA criteria by 2.5 to 5 times at stations at the mouth of Hylebos Waterway and near the ASARCO smelter. Bulk sediment analyses found PCB concentrations of 536, 103, and 26 ppb at the lower turning basin of Hylebos Waterway, Old Tacoma, and off Pier 23 between Blair and Hylebos Waterways, respectively. Sediment relationships to biota are discussed in Section 4.0, Existing Biological Environment.

The only directly comparable studies by others include the Corps' Blair and Sitcum Waterway studies (Corps of Engineers 1979) and the PCB

work of Riley et al. (1981). The latter study results compared well with those of the COBS effort. The Corps of Engineers (1979) indicated Blair and Sitcum sediments (nine stations) had higher levels of arsenic and lead than noted in the two COBS stations. This may be due to nonuniform concentrations of these heavy metals or to different sampling and/or laboratory techniques.

Malins et al. (1980) indicated that sediments in Sitcum Waterway contain high concentrations of arsenic, cadmium, chromium, copper, lead, zinc, and certain organic compounds. In fact, chromium, copper, lead, and zinc were found in higher concentrations in Sitcum Waterway than at any other location examined in the study. Hylebos Waterway was found to be relatively high in cadmium, chromium, copper, lead, zinc, and organic compounds. A station near Old Tacoma, off Ruston Way, was found to be high in concentrations of copper, lead, zinc, and certain organic compounds. Zinc was also found in high concentrations in sediments near the ASARCO smelter. Malins et al. continued this study into 1981; the summary of the additional data is being reviewed by the NOAA/MESA Puget Sound Project Office and was unavailable for incorporation into this report.

Sedimentation rates were found to be generally low except in the vicinity of the bay's major sediment source, the Puyallup River. Based on historical records (1923-1974), the sedimentation rate for an area between Blair and Sitcum Waterways was estimated at about 3 inches (8 centimeters [cm]) per year. Higher Blair Waterway rates were estimated at about 1 to 2 feet (30 to 60 cm) per year from more recent data (Carpenter et al. 1978). The present mouth of the Puyallup River has accumulated as much as 50 to 60 feet (15 to 18 m) of sediments since rechannelization in the early 1900s.

Historic records of Puyallup River delta growth trends indicate the leading edge of the delta has advanced about 1,200 feet (365 m) seaward since 1923, including about 900 feet (275 m) between 1946 and 1979. This advancement has generally occurred without hindrance since dredging in this area was terminated before 1910. The Puyallup River delta is also advancing laterally with sediment depths as much as 20 feet (6 m) and more between St. Paul Waterway and the river mouth.

Maintenance dredging of sediments is evaluated from an historical perspective as a component of the Land and Water Use Technical Report (Volume II). The U.S. Army Corps of Engineers, Seattle District, is currently proposing to expand dredging activities in Blair and Sitcum Waterways to create and maintain deeper, more navigable channels.

3.5 CLIMATE AND AIR QUALITY

Climatic conditions, air quality conditions, and major point sources of air emissions were characterized in the COBS area. Based upon available data, current nonattainment areas for total suspended particulates (TSP) were mapped. The COBS study area is part of a larger nonattainment area for photochemical oxidants and carbon monoxide. A large part of the COBS study area (the port industrial area and the northeastern portion of the Tacoma downtown area) is a nonattainment area for TSP. Arsenic and lead levels in the COBS area were summarized, and lead values in air were found to be below the EPA standards. No current arsenic standard exists. Some 26 major air pollution sources were mapped in the COBS area along with the tons per year of selected chemicals emitted from each source. Major point sources include the St. Regis Kraft Mill (particulate matter, nitrogen oxides), the ASARCO copper smelter (sulfur dioxide, heavy metals), the U.S. Oil Refining Company (hydrocarbons, volatile organic compounds), and Kaiser Aluminum (carbon monoxide).

3.6 NOISE

The noise study described principal noise sources within the COBS area including sources from the North Shore, Port Industrial Area, and South Shore. Data analysis indicated that automobile and truck traffic along major roadways generally constitutes the primary noise source in the study area. However, the ASARCO smelter, railroad noise (passbys and wheel flange squeal), and other noises associated with industrial activity are also prominent noise sources in certain locations.

Noise levels imposed on sensitive receptors (primarily single-family residences in the COBS study area) are generally within acceptable levels. Only at certain locations along Marine View Drive and Ruston Way/Schuster Parkway do traffic, and in the latter case, train passbys, impose temporary noise levels in excess of acceptable standards on sensitive receptors.

4.0 EXISTING BIOLOGICAL ENVIRONMENT

4.1 GENERAL

The biological species and assemblages of Commencement Bay (or any other locale) are reflective of the existing physical and chemical regimes in the bay. They can be assumed to have changed markedly since the turn of the century as the nature of the habitat has evolved under man's pressure for industrial, urban, and agricultural development in Commencement Bay including its drainage area.

The existing Commencement Bay marine ecosystem receives energy (organic carbon) inputs from a variety of sources including:

- In-situ primary production of planktonic algae.
- In-situ primary production of attached benthic macro- and micro-algae.
- Organic detritus brought to the area by the Puyallup River and other surface drainages and from central Puget Sound via marine circulation patterns.
- Organic material discharged or dumped by man's industrial urban activities (e.g., forest products handling and processing, chemical processing, domestic and industrial wastes).

Although no direct measurements of any of these energy inputs have been made, some general impressions have been formulated in the course of work on COBS.

Filterfeeding species were of relatively minor importance except for some zooplankters (e.g., calanoids, mysids) that were important fish food organisms in the outer bay. Benthic filterfeeders (mussels) that were present appeared to be markedly smaller than members of the same species elsewhere in Puget Sound. This suggests that planktonic primary production is probably of relatively minor significance in the organism groups studied (see also Simenstad et al. 1979). Benthic macroalgae (seaweeds) are likewise of minimal importance, in part due to the limited hard substrate available for attachment and growth. Although not quantified, there was

an apparent lack of macroalgal growth within the waterways even where hard substrates were available. As noted by Simenstad et al. (1979), macroalgal productivity tends to contribute to higher trophic levels more through detrital pathways than directly as food for grazing herbivores. This may be especially true for the rockweed Fucus which is the dominant intertidal macroalgae where suitable substrate occurs in the study area.

Organic detritus brought to the bay by natural marine and freshwater surface circulation patterns is probably of considerable significance in providing an energy resource for the predominantly detritus-based benthic food web of Commencement Bay. The importance is probably greater in the open waters of the bay than inside the waterways where detrital inputs from man's activities are of greater importance. Organic matter may be in forms ranging from bark, sawdust, shavings, and chips from wood products processing, to pilings and lumber from pier fires or general decay, to pickles or other industrial wastes, to municipal sewage. At several stations within the waterways (e.g., 1, 6, 7; see Invertebrates Technical Report, Volume IV), organically enriched surficial sediments were exploited by high densities of a few species of detritivores. As in all cases of detritus utilization by marine invertebrates, microbes (bacteria) inhabiting the surface of detrital particles may be of greater importance as a usable food resource than is the detritus itself. The most important fish species in Commencement Bay feed primarily on detritivorous invertebrates. This indicates that much of the food web of the area is dependent on the high detrital inputs and/or past deposits in the bay.

4.2 BENTHIC INVERTEBRATES

The infaunal invertebrate communities of the Commencement Bay study area were primarily composed of bivalves and polychaete worms. The polychaete families Cirratulidae, Nephtyidae, Lumbrineridae, and Spionidae contained the most common and numerous species. Most representatives of these groups are deposit feeders or surface feeding detritivores that exploit the organically enriched surficial sediments. Polychaete abundance was highest at subtidal stations of transects in the study area

and lowest at intertidal stations. Bivalves were common and several species of Macoma and Axinopsida serricata, all deposit feeders, were the most numerous ones encountered. The bivalves were most numerous subtidally at all stations except for Hylebos Waterway at the 11th Street Bridge and City Waterway at the mouth of Wheeler Osgood Waterway. No seasonal abundance patterns were evident in the infaunal communities.

Epibenthic invertebrate communities were numerically dominated by harpacticoid copepod species (detritivores, herbivores) but also contained significant numbers of gammarid amphipods (primarily detritivores) and calanoid copepods (herbivores). Harpacticoids were most abundant at subtidal stations in the lower turning basin of Hylebos Waterway, Commencement Park, City Waterway at the mouth of Wheeler Osgood, Middle Waterway, and the mouth of the Puyallup River. Harpacticoids were most numerous intertidally at Commencement Park and the mouth of the Puyallup River. Gammarid amphipods were most abundant at subtidal stations near Browns Point, Commencement Park, City Waterway at the mouth of Wheeler Osgood, Middle Waterway, and the mouth of the Puyallup River. The Browns Point station had the highest numbers and species diversity of gammarids in the study area. Calanoid copepods should be considered as neritic (surface water) organisms rather than epibenthic; however, they were commonly taken by the epibenthic sampling gear. Calanoids were most abundant at all stations along Hylebos Waterway, Browns Point, and Commencement Park. Most of the epibenthic organisms underwent a seasonal shift in abundance levels with highest levels observed in April and lowest in November.

Sediments in the study area are generally classified as sandy silts and silty sands. The polychaetes were somewhat more abundant in muddier sediments while no real difference was detectable for bivalves. Harpacticoids, gammarids, and other epibenthic crustaceans were most abundant in soft mud habitats having an organic debris surface layer and less common in sandy substrates and dredged channel bottoms. Sediment quality in the study area, in terms of chemical oxygen demand (COD), volatile solids, oil-grease, and sulfides, was relatively poor at sample stations in City Waterway, off Commencement Park, and between the Puyallup River and Milwaukee Waterway. Abundance levels of several taxa were high at these

same stations, while diversity indices were low, indicating a stress due to organic enrichment or sediment degradation. Sediment quality can influence benthic invertebrate community composition through decreased survival time for sensitive species. For instance, sediment bioassays using a gammarid amphipod have shown a significant difference in survival times between animals exposed to sediments from Hylebos Waterway and those exposed to sediments from a control area (Swartz 1981). More studies of this nature are in progress (Swartz, in press).

Several toxicants were present in water samples from certain locations that may be affecting the benthic invertebrate populations. Waters at the Hylebos Waterway mouth had a PCB value during October (0.64 μg/l) which exceeds the EPA 24-hour average criterion for protection of both freshwater and saltwater organisms. Three December water quality stations in Hylebos Waterway had arsenic values at the surface ranging from 30 to 50 μg/l compared to an EPA criterion of 40 μg/l for short-term effects on aquatic vertebrate embryos and larvae. Copper in a composite water sample from three depths in City Waterway was measured at 9 μg/l, exceeding the established EPA 24-hour average criterion for saltwater organisms. Sixteen of the 33 water quality stations in October had instantaneous copper values that exceeded the EPA 24-hour average criterion. These toxicants were generally at their highest levels near the water surface in December 1980, suggesting an input into the system from stormwater runoff, bank seepage, or industrial discharges rather than mobilization from bottom sediments. Other COBS data generally support this hypothesis. Benthic invertebrate communities were usually the poorest in terms of species abundance and diversity at intertidal stations. One possible explanation is that these stations, in contact with surface waters as the tide rises and falls, have a higher probability of exposure to potential toxicants than do the subtidal stations.

Several depth-related patterns were observed within the benthic invertebrate communities. Density of infaunal invertebrates increased with depth, and depth-related groups of stations were formed during classification analysis. Outer bay stations that had steeper shoreline gradients, and thus were closer to deep water than stations in waterways,

had higher densities of neritic organisms such as calanoid copepods. Depth-related patterns were not evident in the epibenthic communities and this can be partly explained by the mobility of these organisms.

Major predators on the infaunal invertebrates included shorebirds in exposed intertidal habitats and resident marine fish and macroinvertebrates (primarily crabs) on flooded intertidal and subtidal habitats. Epibenthic invertebrates were preyed upon by outmigrating juvenile salmonids. Larger epibenthic forms, such as crangonid shrimp, were consumed by flatfish.

4.3 COMMERCIAL AND RECREATIONAL SHELLFISH

There is currently no commercial fishery for shellfish in Commencement Bay; however, recreational shellfishing is widespread. Dungeness and rock crab are the target species and most crab fishing occurs along the Marine View Drive shoreline, along Hylebos Waterway, and along City Waterway. Although fishing effort appeared to be high during the study period, catches were low and quantitative catch data were generally lacking.

Two species of shrimp are sought by recreational fishermen in Commencement Bay. Coonstripe shrimp are taken in pots along Hylebos Waterway and ghost shrimp are dug (for use as bait) in Hylebos Waterway and Middle Waterway mudflats.

Shrimp and crab from Commencement Bay have been found to contain lesions in the gills, hepatopancreas, connective tissues, and bladder with the hepatopancreas and bladder most commonly affected (Malins et al. 1980). In the Malins study shrimp from Commencement Bay waterways had a 19 percent average annual frequency of hepatopancreatic lesions. Crabs from Commencement Bay waterways contained lesions in the hepatopancreas and bladder at average annual frequencies of 27 percent for both organs (Malins et al. 1980).

Crab and shrimp from Commencement Bay were generally found to have concentrations of organic contaminants in their tissues that reflected the chemical composition of the sediments in the area where the animals were collected (Malins et al. 1980). In areas of Commencement Bay where shrimp and crab are most abundant, such as Hylebos Waterway, COBS sampling results indicate the sediments contain PCBs, copper, and zinc at concentrations which could produce water approaching 1980 EPA water quality criteria. It therefore follows that at least one mechanism for incorporation of hazardous compounds contained in the sediments into various invertebrate tissues is via these organisms feeding on detritus or secondarily consuming detrital particles during feeding.

The types of lesions studied by Malins et al. (1980) are a result of chronic rather than acute exposure; the latter can cause organism mortality before defense mechanisms can be activated. It is difficult to document acute toxicity events in benthic invertebrates since these organisms are generally out of sight and do not float to the surface after death. However, the presence of chronic injury effects in crab and shrimp species usually indicates that acute toxicity effects may occur in more sensitive benthic invertebrates. Relatively low species abundance and species diversity values may be linked to contamination effects that exclude more sensitive organisms from areas of high contamination stress.

4.4 FISH

There is an obvious link between the water quality of any estuary and the fish population residing there. The present water quality conditions in Commencement Bay, while degraded over the original natural river delta and saltmarsh, are apparently somewhat improved over years past. Unpublished reports in Washington State Department of Ecology (WDE) files (Washington Pollution Control Commission 1959) state that, since approximately 1950 fish kills in the spring months in Hylebos Waterway had "become somewhat commonplace." An incident of high mortality of herring in February 1959 was described in one document. Sulfide and copper concentrations allegedly were high enough to have caused these

mortalities. A March 1959 state survey in Hylebos Waterway failed to locate resident fish species (perch, flatfish, sculpins, etc.) by hook-and-line and by visual inspection of typical fish habitats (Water Pollution Control Commission 1959). The memorandum documenting this survey infers that stress conditions in Hylebos Waterway existed for a long enough period of time to prevent resident fish from migrating into or inhabiting the area. The 1980 COBS sampling (see Fish Studies Technical Report, Volume III), while much more quantitative than the 1959 state survey, located resident and migratory fish species in Hylebos Waterway. Comparisons of extremes in water color, pH, and low dissolved oxygen in the 1959 state report with the COBS data from 1980 indicate a general improvement in water quality.

4.4.1 Juvenile and Adult Salmonids

Juvenile chinook salmon were the most abundant juvenile salmonids collected in Commencement Bay in 1980. The total catch was approximately twice that of the total catch for all other salmonid species combined (fishing effort for all species considered equal). Juvenile chinook were present in Commencement Bay from early April to late July, peaking in abundance in late May. Highest beach seine catches were at the mouth of the Puyallup River, the Hylebos Waterway mudflats at the 11th Street Bridge, near Browns Point, and in Middle Waterway. Highest purse seine catches were in Milwaukee Waterway, inner Sitcum Waterway, and at the mouth of City Waterway. In general, chinook appeared in beach seine catches early in the sampling program and in purse seine catches toward late May.

Juvenile pink salmon were the second most abundant salmon collected in Commencement Bay in 1980. They were present from late March to June with a peak in abundance during mid to late April. Ninety percent were collected by beach seine. Areas with the highest catches were Commencement Park, Hylebos Waterway mudflats at the 11th Street Bridge, and near Browns Point.

Juvenile chum salmon were the third most abundant salmon collected in Commencement Bay in 1980. Eighty percent of the total number of individuals were taken by beach seine. Chum juveniles were present in beach seine catches from April through May. The data do not indicate a peak in abundance. The majority of the beach seine caught chum were taken at the Hylebos Waterway mudflats at the 11th Street Bridge and near Browns Point. Small numbers of chum were collected by purse seine in June and July at the mouth of City Waterway, Milwaukee Waterway, and inner Sitcum Waterway.

Only 68 juvenile coho salmon were collected during 1980, and 84 percent of these were caught during May. This small number was surprising since adult coho salmon make up the majority of the commercial and recreational catch in Commencement Bay. One possible explanation for this is that the gear used did not adequately sample the habitat occupied by the juvenile coho.

Twenty cutthroat trout and five steelhead were collected during the study. All, except for one steelhead, were collected by beach seine and the majority were taken from the station below the Cliff House Restaurant and at the Puyallup River mouth.

Results from the Puyallup Nation 1980 beach seining program were compared with COBS data. Based on cpue data, their catches of juvenile chinook were generally comparable to COBS data in both numbers and areas of highest catch. Puyallup Nation data for pink salmon were also comparable except that they had higher catches in City Waterway than did COBS sampling. Chum salmon were also collected in very low numbers by the Puyallup Nation. The Puyallup Nation collected approximately 20 times the number of coho as did the COBS effort with a peak catch occurring in early May.

No field studies were conducted on adult salmonids in the study area; however, general information on adult runs in the bay and rivers/creeks as well as on current sports and commercial fishery activities were reviewed. Information on adults was limited to that pertaining to

commercial and recreational fishing for salmon in Commencement Bay. Treaty Indians were the only commercial fishermen allowed to fish within Washington Department of Fisheries (WDF) Marine Area 11A during 1980, although this area has been opened at times in the past to non-Indian commercial fishermen. Sport fishing for salmon is popular in Commencement Bay with three areas experiencing the most fishing activity: the Puyallup River mouth, the Point Defiance area, and the Browns Point area.

Three freshwater drainages into Commencement Bay support anadromous salmonid populations. The Puyallup River basin is by far the largest and most important system, supporting runs of spring and fall chinook, coho, chum, pink, and steelhead. Puyallup Tribal Fisheries Division biologists have observed sockeye salmon in Kapowsin Creek, a tributary to the Puyallup River. Hylebos and Wapato Creeks, two relatively small, independent drainages that flow into Commencement Bay, also support natural coho and chum populations, although the Wapato Creek system has had limited production in recent times.

Chinook salmon have both a fall and spring run through Commencement Bay waters, with the fall run usually the largest. The WDF management period for fall-run chinook in Commencement Bay is usually from August through mid-October; the period for spring-run chinook is usually from mid-April to the end of June.

Coho salmon are the predominant sport and commercially caught species. The WDF management period for coho usually runs from the first week in September to the first week in November. A peak in the sport fishery for coho can occur from as early as June to as late as September.

Chum salmon are generally low in numbers in the sport catch since they do not readily take lures. The WDF management period for chum usually runs from the first week of November to the first week of January.

Pink salmon runs occur primarily in odd-numbered years. The WDF management period for pinks usually runs from the end of July to the middle of September with the peak of the catch often occurring in August.

Sport fishing for pinks extends from April through mid-September, with good fishing usually in August.

Winter-run steelhead trout are known to occur in Commencement Bay and the Puyallup River; peak freshwater catches are in December and January.

As previously mentioned, toxic substances have been identified in surface water samples from Hylebos Waterway and City Waterway that could affect aquatic organisms. Elevated levels of arsenic and PCBs in Hylebos Waterway and copper in City Waterway may affect juvenile salmonids during their residency period in Commencement Bay. With some exceptions, catch per unit effort (cpue) values for all species were relatively low in the inner waterways compared to stations near the mouths of waterways and along the outer bay shoreline. Exceptions included the Hylebos Waterway mudflats at 11th Street (for chinook salmon only), purse seine catches in Milwaukee Waterway and inner Sitcum Waterway, and a beach seine catch in Middle Waterway. Many other factors could contribute to juvenile salmon distributions including available prey species which appear to be influenced by sediment and/or water chemistry.

Shoreline configuration and water depth seem to play a major role in the early distribution patterns of outmigrating juvenile salmonids. Early (April and May) chinook juveniles in Commencement Bay were predominately found along shallow, nearshore beach habitat. Toward late May, chinook began appearing in purse seine catches from deeper water along the face of pier aprons. Juvenile pink salmon showed a strong preference for mudflat and beach habitat, seldom being collected in purse seines along pier aprons. Juvenile chum salmon used nearshore beach and shoreline habitat during their early residency and showed a shift to deeper water along piers after early June.

Some nearshore, soft mud habitats had high cpue values (mouth of the Puyallup, Milwaukee Waterway), while others were important feeding areas for juvenile salmonids based on the results of stomach content analysis (Hylebos Waterway mudflats at 11th Street Bridge, City Waterway at the

mouth of Wheeler Osgood). Stressed benthic invertebrate communities indicated by high species abundance but generally low species diversity were observed in certain areas (e.g., City Waterway and between the Puyallup River mouth and Milwaukee Waterway) where the worst sediment conditions (in terms of chemical oxygen demand, sulfides, volatile solids, and oil/grease) were observed. Juvenile salmon rearing in these areas and feeding on the organisms in the sediments may be affected by toxicants in the sediments or in their prey items. The effects, if any, from toxicants in the sediments of Commencement Bay on juvenile salmonids are unknown at present but may be important.

A general feeding pattern was observed for all juvenile salmonids in Commencement Bay. Juveniles fed on epibenthic prey in nearshore environments during the early stages of their outmigration period and shifted to neritic organisms during the later stages of their residency. Harpacticoid copepods were the most abundant prey item taken by all four salmon species studied. Harpacticoids were found in highest numbers in fish collected within Hylebos Waterway (compared to numbers in fish stomachs at other Commencement Bay locations) even though harpacticoids were generally more abundant at stations southwest of the Puyallup River. Harpacticoid and calanoid copepods, gammarid amphipods, and drift insects made up over 90 percent of the prey items taken by juvenile salmonids.

4.4.2 Resident Marine Fish

Marine fish were most abundant in the study area during the summer and least abundant during winter. Flatfish were the most numerous group collected and were present in each sampling period from each station. English sole, rock sole, flathead sole, C-O sole, sand sole, starry flounder, and speckled sanddab were the most common flatfish species collected in the study area. Also common, but less abundant, were Pacific staghorn sculpin, Pacific tomcod, ratfish, copper rockfish, and snake prickleback. Species taken predominately from the waterways included English sole, flathead sole, Pacific staghorn sculpin, Dover sole, ratfish, Pacific tomcod, and starry flounder, while species more common along the open water shoreline included rock sole, C-O sole, and

several species of rockfish. Low salinity conditions near the Puyallup River mouth were a factor in the observed higher abundance of starry flounder and Pacific staghorn sculpin at that site, compared to other stations. Both species are tolerant of low salinity, estuarine conditions.

External condition of marine fish appeared good. Several species showed infestation by the nematode worm Philometra sp.; however, the frequency of occurrence of this parasite appeared to be no greater than for other areas of central and southern Puget Sound. However, NOAA/MESA studies in Commencement Bay have demonstrated a high incidence of internal abnormalities or disease in several resident marine fish species in Commencement Bay (Malins et al. 1980) and these diseases have been statistically correlated with high levels of heavy metals and organic chemicals in the waterways. Bioassays with invertebrate prey species, conducted by Swartz (1981), indicated that sediment toxicity may not be a problem in deeper parts of Commencement Bay, but may be in the waterways (especially Hylebos Waterway) where sediments appeared to be contaminated with toxic materials at concentrations capable of causing acute mortality.

Resident flatfish in Commencement Bay are facultative benthivores, that is, they feed primarily on benthic invertebrates such as polychaetes and bivalves but also feed on epibenthic crustaceans such as gammarid amphipods. Invertebrate numbers/types observed in flatfish stomach content analyses were similar to the infaunal distribution in the study area although considerable between-habitat and seasonal variation was observed.

Prey items of marine fish were widely distributed throughout the bay. Infaunal prey items, essentially bivalves and polychaetes, were present at nearly every subtidal station in the study area. Epibenthic prey items were also widespread but were most numerous in subtidal areas in the following locations: Commencement Park, City Waterway at the mouth of Wheeler Osgood, Middle Waterway, and the mouth of the Puyallup River.

There is currently no commercial fishery for resident marine fish in Commencement Bay. Recreational fishing is common, however, and is concentrated along Ruston Way and City Waterway fishing piers and other areas open to public access. A recent survey by Noviello (1981) indicated that 95 percent of the fish caught in Commencement Bay are from the southwest side of the bay, with 70 percent caught at or near the Old Town and Point Defiance fishing piers. At these piers the catch was dominated by hake, pollock, and Pacific tomcod. From Middle Waterway to Browns Point the fishing effort is much lower, possibly due to restricted access, and the catch is dominated by pile perch and striped seaperch (Noviello 1981).

4.5 BIRDS

Commencement Bay provides habitat for relatively large populations of both resident and migratory bird species. The Commencement Bay area in general provides resting and feeding habitat for many species of migratory shorebirds and waterfowl. Commencement Bay functions as both a stopover point during migratory flights and as an overwintering area.

Bird distribution in the bay is determined by several factors including habitat availability, feeding behavior, and nesting preferences. Shorebirds and wading birds, such as turnstones, sandpipers, and herons, are exclusively nearshore in distribution and were commonly observed along the shoreline of the outer bay and waterways and in upland areas. Concentration areas of shorebirds and waders included the Hylebos Waterway mudflats and the intertidal area at the Puyallup River mouth. Waterfowl were found in both nearshore waterway and open bay regions with largest numbers sighted along the Marine View Drive and Ruston Way shorelines and along the banks and at the mouth of the Puyallup River. Gulls and terns were observed throughout Commencement Bay in both nearshore and open bay habitats. Gulls were present in all seasons and were far more numerous than terns, which were present only in late summer. Areas of gull concentration included intertidal mudflats, log storage areas, and abandoned pilings at the mouth of City Waterway. Seabirds were normally sighted in open bay waters and seaward of the waterway mouths. Cormorants

were commonly seen roosting on pilings and bulkheads along Ruston Way. Raptors and shorebirds were generally found throughout the terrestrial portions of the Commencement Bay study area. The forested uplands along Marine View Drive and Hylebos Waterway, Point Defiance Park, along the Puyallup River, and wetland areas were all habitats used by raptors and passerines.

Intertidal mudflats in Commencement Bay supported feeding activity by shorebirds, waterfowl, gulls, and herons. Mudflats in Hylebos Waterway and at the mouth of the Puyallup River were the major intertidal feeding areas. Open water areas and some waterways were used as feeding habitat by seabirds and diving ducks (these species also probably feed over mudflats at high tide). The belted kingfisher and great blue heron were commonly seen feeding along the shoreline of the waterways and Puyallup River; both species often used man-made structures like floating piers and pilings for perching and feeding. Forested, brushy, and undeveloped terrestrial wetland (marsh, swamp, etc.) sites were used for feeding by raptors and passerines. Raptors are known to feed on small mammals present in these habitats while passerines feed on insects, seeds, and small fruits.

A pair of bald eagles maintain an active nest site in Point Defiance Park. Although not actually within study area boundaries, this nest site is important since bald eagles are federally designated as threatened within the State of Washington and the birds may occasionally pass over the study area. A peregrine falcon has been sighted around Commencement Bay during the previous two winters and may use adjacent upland areas as wintering habitat. This species is federally designated as endangered.

Several bird species nest within the Commencement Bay study area. Glaucous-winged gulls maintain a large breeding colony atop boards and pilings of an abandoned pier between Middle and St. Paul Waterways. Bluffs along the Marine View Drive shoreline from 11th Street to Browns Point are used for nesting by belted kingfishers and barn owls. These species construct burrows in the side of the bluffs. Barrows goldeneye nest among the pilings along Milwaukee Waterway, one of the few known

nesting sites for this species in coastal western Washington. Mallards nest in vegetation along the banks of the Puyallup River from its mouth to the Interstate 5 bridge and occasionally nest in wetland areas between the Puyallup River and Blair Waterway. A pair of red-tailed hawks nest in a large cottonwood tree on the southeast bank of the Puyallup River between the Tacoma sewage treatment facility and Highway 99. Several pairs of Canada geese nest along the northeast shore of Hylebos Waterway in the vicinity of the 11th Street Bridge mudflats. Passerine species nesting occurs throughout the terrestrial portion of the Commencement Bay study area.

A primary disturbance to birds in Commencement Bay has been the loss of intertidal and freshwater wetland habitat. Development activities such as filling intertidal and marsh habitats, channelization of the Puyallup River, and placing riprap structures along the shoreline have all contributed to habitat loss. This loss has certainly led to a decline in abundance and use of the area by most bird species. Adverse impact on intertidal prey species may also result in a reduction in bird use of available remaining habitat in the bay.

4.6 WETLANDS*

The areal extent of Commencement Bay wetlands, particularly the salt marshes, has been greatly reduced by previous and ongoing development activities. However, seven wetland areas remain that have been identified as having unique and/or important functional characteristics. Six major wetland habitat types are represented including open water, intertidal areas lacking macrovegetation, salt marsh, brackish marsh, freshwater marsh, and swamp.

Two wetland complexes are found near the Bonneville Power Administration power substation. One is a 4.5-acre (1.8 hectares) seasonal pond-marsh complex that provides bird nesting, resting, and feeding habitat. The other is a 7-acre (2.8 hectares) system of open water, cattail marsh, and seasonal marsh that also provides bird nesting, resting, and feeding habitat.

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*Note: Some filling occurred since the July-August 1980 field surveys were completed; thus, some wetland areas have been reduced from those described herein.

The tidal marsh in Hylebos Waterway near the 11th Street Bridge consists of 9.6 acres (3.9 hectares) containing cattail, spike rush, bulrush, redtop, and saltgrass. Upland areas contain both shrubby vegetation and deciduous trees. This tidal marsh functions in sediment removal and detrital export, bird nesting, resting, and feeding habitat, and small mammal nesting and cover.

A 25-acre (10.1 hectares) seasonal marsh along Milwaukee Way contains broad areas of spike rush and redtop interspersed with shallow ponds, mudflats, and a cattail marsh. This wetland area is valuable as bird nesting, feeding, and resting habitat and is potentially valuable for storage of urban runoff.

South of the intersection of Marshall Avenue and the East-West Throughway is a 12-acre (4.85 hectares) seasonal marsh on land owned by the Port of Tacoma. The marsh is dominated by redtop and saltgrass and is valuable for storm water runoff storage, bird nesting, resting, and feeding habitat, and small mammal cover and resting habitat.

A 4.1-acre (1.65 hectares) wetland complex exists between Taylor Way and Alexander Avenue near the Tacoma City Light power substation. This is a diverse wetland habitat that includes Spiraea swamp, a seasonal spike rush and redtop marsh, grassland and deciduous trees, and a cattail marsh. The vegetation diversity, combination of wetland and upland habitats, and seasonal standing water provides feeding, nesting, and resting habitat for a variety of bird and small mammal species.

Along the north side of Hylebos Waterway, downstream of Lincoln Avenue, there is an 80-acre (32.4 hectares) wetland complex. Intertidal flats cover 69.5 acres (28.1 hectares) but much of this is used for log storage. The salt marsh area covers 10.5 acres (4.25 hectares). This wetland area is unique in Commencement Bay due to its mixture of marine intertidal and freshwater wetland habitats but its biological value is currently limited due to log storage. It does provide nesting, resting, and feeding habitat for several bird species.

A 3.9-acre (1.6 hectare) wetland complex exists near Milwaukee Way and Pacific Highway. It is a series of interconnected open-water ponds surrounded by cattail marsh. It has value as bird and mammal feeding, nesting, and resting habitat.

The productivity of wetland areas depends upon such factors as presence/type of emergent vegetation and degree of fresh and salt water mixing. For purposes of the Commencement Bay study, wetland areas are ranked as having low, moderate, or high productivity. Low productivity is defined as being less than 600 gm (dry weight)/m^2/year, moderate productivity as 600 to 1,200 gm (dry weight)/m^2/ year, and high productivity as greater than 1,200 gm (dry weight)/m^2/year. These rankings are based on a review of current wetlands literature (see the Wetlands Report in Volume III).

Open water areas, including Commencement Bay, isolated ponds, ponds with regular freshwater input, and tidal rivers and creeks have generally low productivity. Excluding the bay and waterways, these areas cover approximately 131.6 acres (53.25 hectares). Intertidal areas including intertidal flats and beaches have low productivity, especially in areas impacted by log rafts. Areas without log rafts may have quite high secondary productivity. Intertidal flats and beaches cover approximately 97.4 acres (39.4 hectares) in the study area.

The approximately 11 acres (4.45 hectares) of salt marsh wetlands in the Commencement Bay study area have moderate productivity. Brackish marsh covers about 3 acres (1.2 hectares) and has high productivity due primarily to tidal mixing which allows detrital export into the marine waters. Freshwater marsh habitats cover approximately 91.4 acres (36.9 hectares). Productivity is high in cattail and reedgrass dominated freshwater marshes, high in tidal freshwater marshes, and moderate in seasonal marshes. Swamp habitat covers less than 2 acres (0.8 hectare) of the Commencement Bay study area; productivity level is low to moderate.

Nine potential wetlands rehabilitation and creation sites in the study area were cursorily evaluated. These sites include areas in Wheeler Osgood Waterway, City Waterway, Middle Waterway, St. Paul Waterway, the Puyallup River, and Hylebos Waterway (see Volume III, Wetland Studies Technical Report). A major consideration and tradeoff in any such activity in shallow freshwater or marine areas is the impact on juvenile salmonid populations known to occupy the potential wetland creation site.

5.0 EXISTING HUMAN ENVIRONMENT

5.1 GENERAL

The COBS study area is dominated by the City of Tacoma on the south shore of Commencement Bay and the large Port of Tacoma industrial area and associated waterways on the southeast (landward) end of the bay. Man's use of the COBS study area has been directly influenced by its close proximity to deep, navigable waters. The following sections highlight the historic and present land and water use pertinent to Commencement Bay and the industrial waterways.

5.2 HISTORIC PERSPECTIVE

Commencement Bay has been a focal point for human activity for centuries (see the Land and Water Use Technical Report [Volume II] for a complete historical perspective of the study area). Prior to non-Indian settlement, members of the Puyallup Nation inhabited several villages on the bay and the tideflats to the east. A continuous line of small settlements stretched along the south shore of the bay for approximately 1 mile [1.6 km] from what is now the Tacoma Central Business District (CBD) to the present location of Stadium High School. The Puyallup Nation used the waters of Commencement Bay and the Puyallup River for fishing, shellfishing, and water transport between villages. Upland areas of the study area were used for hunting small game.

Although first reported by non-Indian explorers in the late 1700s, the Commencement Bay area was not actually settled by Europeans until 1852, when Nicholas Delin completed and began operating a sawmill on what is now City Waterway. In 1854, the Medicine Creek Treaty was signed. This treaty relegated the members of several local tribes, including the Puyallup Nation, to reservations. The remainder of the area traditionally used by the Puyallups was ceded to the United States for non-Indian settlement. This area included the south shore of Commencement Bay from the present site of the City of Tacoma to Point Defiance. The new Puyallup Reservation encompassed what is now southeast Tacoma, Browns

Point, Dash Point, most of the area now occupied by Fife and Milton, and an area to the east of what is now City Waterway. This reservation has since been significantly reduced in size through alienation of Indian lands.

During the 1860s, a substantial non-Indian settlement had developed in the Old Tacoma area. This settlement, first known as Commencement City and later as Tacoma, boasted a mill, wharf, and a number of residences. With the advent of the Northern Pacific Railroad in 1873, the town center was shifted to the site of the railroad terminus located 2 miles (3.2 km) east of Old Tacoma. The present-day Tacoma CBD developed around this latter site. The City of Tacoma expanded rapidly during the period 1870-1890. Extensive water-oriented industrial activities (coal bunkers, warehouses, wharves) dominated the south shore of Commencement Bay. By the early 1900s, the entire south shore of Commencement Bay from City Waterway to the site of the present-day ASARCO copper smelter was an "unbroken linear complex representing lumber, boatbuilding, grain, and shipping firms" (City of Tacoma 1981).

Due to the rapid utilization of available shorelines to accommodate industrialization and urbanization, developable lands adjacent to navigable waters were soon scarce. Major modifications to existing shorelines were soon undertaken along both the south shore and the tideflats at the east end of the bay. During the rapid industrial expansion in the late 1800s, the steep bluffs along the south shore were undercut to create a narrow strip of flat land adjacent to the water. Additional fill was placed in subsequent years to create the approximate shoreline configuration that exists today. In the 1920s, this narrow shelf supported a road and the main trunk of the railroad, much as it does today (Schuster Parkway/Ruston Way and the mainline of the Burlington Northern Railroad). Also in the late 1800s, dredging of the City Waterway was initiated. Industrial development of the tideflats area began in 1918 with the formation of the Commercial Waterway District. Subsequent dredging and filling over the next 60 years formed and expanded the industrial waterways of the port industrial area, including the Port of Tacoma (see the Land and Water Use Technical Report [Volume II] for a discussion of dredge/fill

history and quantities). These activities virtually eliminated the natural tidelands and salt marshes that once dominated the east end of the bay.

The development of substantial new industrial lands through dredging and filling allowed continued development of a wide variety of land uses on adjacent shorelines and the continued growth of the greater Tacoma area.

5.3 PRESENT LAND AND WATER USE

The COBS study area is generally urbanized. As a result, the shorelines of Commencement Bay support commercial, industrial, institutional, and recreational uses as well as open spaces. The Tacoma CBD supports a mix of urban uses dominated by intensive commercial uses. The port industrial area is dominated by water-oriented industrial uses. Residential uses, with some commercial and industrial uses interspersed, dominate the south shore from the Tacoma CBD to the ASARCO smelter. West of the smelter, Point Defiance Park, a major urban recreational open space, left largely in its natural state, constitutes the dominant land use. Residential uses and open space dominate the north shore of the bay from the entrance to Hylebos Waterway on the east to Browns Point on the west. Steep wooded slopes form buffer zones between shoreline uses and predominantly residential uses located landward along both shores. Land ownership in the study area is generally private; Point Defiance Park is the most significant public ownership.

Commencement Bay and its waterways are used extensively by ships and barges transporting products to and from the commercial and industrial facilities of the port industrial area. Over 18,000 vessels entered and departed Commencement Bay destinations in 1978 alone (the most recent year for which data are available). As indicated in preceding sections of this report, these commercial and industrial activities resulted in the introduction of a variety of toxicants into the bay and its waterway. The introduction of these substances occurs in several ways, including the release of waste products from discharge systems directly to receiving

waters, runoff, leaching from fill materials and sediments, deposition of airborne chemicals and as a result of operational spills during transfer of materials between ships and barges and shore facilities.

The waters of Commencement Bay are also used extensively for recreational purposes. An estimated 30,000 pleasure boat trips are generated to and within Commencement Bay annually. Over 2,500 moorages are available in the 15 marinas in the study area. As described above, sportfishing for salmonids occurs in the area, particularly off Point Defiance, the mouth of Puyallup River, and Browns Point. Recreational bottomfishing occurs along Ruston Way and along City Waterway. Bird watching occurs along both the south and north shore of the bay and at scattered landward locations in the port industrial area. The public use of shoreline areas is greatest at Point Defiance Park, Commencement Park, and the south shore of City Waterway. However, public access to shoreline areas occurs generally along the length of both the south and north shores of the bay.

Land and water uses in the study area are regulated by a number of federal, state, and local plans and policies. These plans and policies are examined in detail in the Land and Water Use Technical Report.

6.0 OVERVIEW

Since the advent of non-Indian settlement in the Commencement Bay area in the 1850s, the physical and biological environments have been substantially altered through rapid industrialization and urbanization. The Puyallup delta, once an extensive marsh with many sloughs and embayments, has been modified through dredging and filling into a complex of industrial waterways separated by peninsulas of land that support a variety of water-oriented industrial uses. The Puyallup River, which once entered Commencement Bay via three main distributaries meandering between marsh islands, has been channelized and diked.

Virtually all of the intertidal area of the former delta has been filled with bottom materials dredged from nearby waterways, clean materials from upland areas, dredged materials from waterway creation and expansion, and solid wastes. Much of the south shore of the bay has also been modified by undercutting the original steep slopes and supplemental filling to form the narrow shelf of land that now supports Ruston Way/ Schuster Parkway and the mainline of the Burlington Northern Railroad.

The creation of large areas of modified shoreline accessible to navigable waters and the subsequent industrial development of these lands have resulted in a substantial change in the natural environmental quality of the area. Discharges of solid and liquid, organic and inorganic industrial wastes, and possible contamination from airborne wastes entering via surface waters, have modified the chemical quality of the waters and sediments in many portions of the bay. However, significant biological activity and productivity continue in the study area. Several species of marine and anadromous fish, especially Pacific salmon, and shellfish use the area for a portion of their life history and are harvested in local recreational, commercial, and subsistence fisheries. Moreover, the revenues and employment generated by the industrial area represent a significant economic benefit to the City of Tacoma, Pierce County, and Puget Sound region. Recent environmental regulations and controls have reduced the inputs of chemicals from earlier (1950s-1960s) levels. There is evidence that fish may now reside in areas from which they were excluded by earlier levels of pollution.

The rapid growth of the Port of Tacoma and Pierce County combined with forecasts of future economic growth potential in the region indicate that the demand for developable industrial land in the Commencement Bay area will continue. A portion of the anticipated demand will be accommodated through infilling of vacant lands and redevelopment of other currently occupied lands in the port industrial area. However, the need for additional filling in existing waterways to accommodate highly specialized and land-intensive industrial activities has already been identified.

Despite the considerable degradation of the quality of estuarine habitat in the bay over the past century, it continues to support important marine resources. The degree to which this reduction has influenced numbers of salmon produced by the bay's tributaries or by other south Puget Sound rivers is unknown. The Commencement Bay estuary, even including its more stressed waterways, is still used by outmigrating juvenile salmon which apparently feed readily on available epibenthic zooplankton. It will be difficult to precisely assess the degree to which further reductions in these feeding opportunities would affect the present level of salmon production. The Commencement Bay Studies completed to date present data designed to characterize the baseline (or existing) condition within the study area. These data are anticipated to provide a basis for the evaluation of the environmental impacts of future development.

The Commencement Bay Study (COBS) completed in this contract is a beginning rather than an end. The initial purpose of assessing the available data was to some degree changed by the explosion of interest and studies by other parties in Commencement Bay. Work is continuing under NOAA/MESA Puget Sound Project Office management, Washington Department of Ecology, EPA Region X, and others. Currently, several public agencies and the Puyallup Nation are involved in preparing a Commencement Bay Response Sheet for Allocation of Superfunds as a first step in implementing the federal Comprehensive Environmental Response, Compensation and Liability Act (of December 1980). This effort would expand the data base for the COBS area many times in preparation of a

remedial plan for cleaning up selected sites. COBS provides an analysis of data up to the end of 1981. This analysis will require additions and modifications as additional data become available in published reports.

The data base available along with that anticipated in the next few months from ongoing studies should be sufficient to initiate remaining COBS contract objectives (1.3,b, c described in Section 1.0 of this volume). Specifically, development of methods of evaluating environmental impacts and assessment of those impacts from various activities, projects, plans, and policies in the study area are now important. In other words, we have initially described the existing environment; the next step is to evaluate the probable impacts/tradeoffs involved in actions proposed in the study area.

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APPENDIX A

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III	Fish	Donald E. Weitkamp, Ph.D., Parametrix, Inc. Thomas H. Schadt, Parametrix, Inc.
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VII	Sediments	William J. Enkeboll, Dames & Moore
	Noise	Steven A. Johnston, Dames & Moore Edward L. Carr, Dames & Moore
	Climate and Air Quality	Walter J. Russell, Dames & Moore
	Aesthetics	Ruth L. Van Dyke, Dames & Moore
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